(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 992 984 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
12.04.2000 Bulletin 2000/15

(51) Int. Cl.7: G11B 5/39, G01R 33/09, H01F 10/08

(21) Application number: 99118413.6

(22) Date of filing: 16.09.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 17.09.1998 JP 26369698

(71) Applicant: SONY CORPORATION
Tokyo (JP)

(72) Inventors:
- Kumagai, Seiji
Shinagawa-ku, Tokyo (JP)
- Nakashio, Eiji
Shinagawa-ku, Tokyo (JP)
- Sugawara, Junichi
Shinagawa-ku, Tokyo (JP)
- Ikeda, Yoshito
Shinagawa-ku, Tokyo (JP)

(74) Representative:
MÜLLER & HOFFMANN Patentanwälte
Innere Wiener Strasse 17
81667 München (DE)

(54) Magnetic tunneling element and manufacturing method therefor

(57) A magnetic tunnelling element in which the tunnel current flows reliably in an insulating layer to exhibit a stable magnetic tunnelling effect. To this end, the magnetic tunnelling element at least includes a first magnetic layer, a tunnel barrier layer formed on the first magnetic layer and a second magnetic layer formed on the tunnel barrier layer. The tunnel current flows via the tunnel barrier layer between the first magnetic metal layer and the second magnetic metal layer. The surface of the first magnetic layer carrying the tunnel barrier layer has a surface roughness (Ra) of 0.3 nm or less.

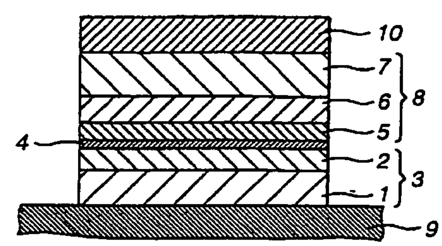


FIG.1

EP 0 992 984 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to a magnetic tunnelling element in which a pair of magnetic layers are laminated via a tunnel barrier layer and in which the tunnel current is caused to flow from one to the other magnetic layer, with the conductance of the tunnel current being changed in dependence upon the ratio of polarization of magnetization of the paired magnetic layers. This invention also relates to a method for manufacturing the magnetic tunnelling element.

Description of the Related Art

[0002] It has been reported that, if, in a layered structure comprised of a thin insulating layer sandwiched between a pair of magnetic metal layers, a preset voltage is applied across the paired magnetic metal layers as electrodes, a magnetic tunnelling effect is displayed, in which the conductance of the tunnel current flowing in the insulating layer is changed in dependence upon the relative angle of magnetization of the paired magnetic metal layers. That is, a layered structure comprised of a thin insulating layer sandwiched between a pair of magnetic metal layers exhibits a magneto-resistance effect with respect to the tunnel current flowing in the insulating layer.

[0003] In this magnetic tunnelling effect, the specific magnetoresistance can be theoretically calculated based on the ratio of polarization of magnetization of the paired magnetic metal layers. In particular, if Fe is used as the material of the paired magnetic metal layers, expectation may be made of the specific magnetoresistance amounting approximately to 40%.

[0004] Therefore, a magnetic tunnelling element having a layered structure comprised of a thin insulating layer sandwiched between paired magnetic metal layers is stirring up notice as an element for detecting an external magnetic field.

[0005] In the above-described magnetic tunnelling element, a metal oxide is routinely used as the thin insulating layer. However, if a metal oxide is used as an insulating layer, pinholes etc tend to be formed, such that shorting tends to be induced between the paired magnetic metal layers. There are occasions wherein, if a metal oxide is used as an insulating layer, the metal oxidation degree is insufficient, such that the tunnel barrier is incomplete such that the magnetic tunnelling effect is not displayed.

[0006] In the conventional magnetic tunnelling element, changes in conductance of the current in dependence upon the relative angle of magnetization of the paired magnetic metal layers, laminated via an insulating layer in-between, that is the magnetic tunnelling effect, were detected. However, with the conventional magnetic tunnelling element, it is difficult to demonstrate the magnetic tunnelling effect reliably such that the conventional magnetic tunnelling element cannot be used for practical application.

SUMMARY OF THE INVENTION

[0007] It is therefore an object of the present invention to provide a magnetic tunnelling element in which the tunnel current flows positively in the insulating layer to exhibit the magnetic tunnelling effect in stability.

[0008] In one aspect, the present invention provides a magnetic tunnelling element including a first magnetic layer, a tunnel barrier layer formed on the first magnetic layer; and a second magnetic layer formed on the tunnel barrier layer formed on the tunnel barrier layer, the tunnel current flowing between the first magnetic layer and the second magnetic layer via the tunnel barrier layer. The surface of the first magnetic layer carrying the tunnel barrier layer has a surface roughness (Ra) of 0.3 nm or less.

[0009] With the magnetic tunnelling element according to the present invention, as described above, since the surface of the first magnetic metal layer carrying the tunnel barrier layer has an average surface roughness (Ra) of 0.3 nm or less, the tunnel barrier layer 2 has its surface planarized to a high degree, so that, with the present magnetic tunnelling element, the interface between the first magnetic metal layer and the tunnel barrier layer and that between the second magnetic metal layer and the tunnel barrier layer are in optimum states to display the magnetic tunnelling effect reliably.

[0010] In another aspect, the present invention provides a method for manufacturing a magnetic tunnelling element at least including a first magnetic metal layer, a tunnel barrier layer and a second magnetic metal layer, laminated together, in which the method includes the steps of forming the first magnetic layer so that its major surface will have an average roughness (Ra) of 0.3 nm or less, forming the tunnel barrier layer on the major surface of the first magnetic metal layer and forming the second magnetic metal layer on the tunnel barrier layer.

[0011] With the manufacturing method for the magnetic tunnelling element according to the present invention, since the first magnetic metal layer is formed so that its major surface will be of the average surface roughness (RA) of 0.3 nm or less, the tunnel barrier layer formed on this major surface can be of optimum surface properties. Therefore, with this technique, the first magnetic metal layer and the tunnel barrier layer can be formed to optimum states.

[0012] In particular, with the magnetic tunnelling element according to the present invention, the surface roughness (Ra) of the surface of the first magnetic metal layer carrying the tunnel barrier layer is 0.3 nm or less. Thus, with the present magnetic tunnelling ele-

ment, the tunnel current is allowed to flow positively between the first magnetic metal layer and the second magnetic metal layer in the vicinity of the tunnel barrier layer. Therefore, the magnetic tunnelling element of the present invention positively exhibits the high magnetic tunnelling effect.

[0013] Also, with the present manufacturing method for the magnetic tunnelling element, the first magnetic metal layer is formed so that its major surface will have an average roughness (Ra) of 0.3 nm or less. Thus, with the present technique, the magnetic tunnelling element can be provided which allows the current to flow reliably between the first magnetic metal layer and the second magnetic metal layer in the vicinity of the tunnel barrier layer. Therefore, with the present manufacturing method for the magnetic tunnelling element, a magnetic tunnelling element exhibiting a high magnetic tunnelling effect can be manufactured reliably.

[0014] Since the high magnetic tunnelling effect can be realized in the present invention, the present invention can be applied with advantage to a high output magnetic head.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig.1 is a cross-sectional view showing essential parts of a magnetic tunnelling element according to the present invention.

Fig.2 is a perspective view showing essential portions of the connection between the magnetic tunnelling element, constant current source and the voltmeter.

Fig.3 is a graph showing the relation between the extrnal magnetic field and the specific magnetoresistance.

Fig.4 is a graph showing the relation between the average roughness (Ra) and the specific magnetoresistance on the surface of the first magnetic metal layer.

Fig.5 is a graph showing the relation between the thickness of the first magnetic metal layer, inclusive of an underlying layer, and the average roughness of the first magnetic metal layer.

Fig.6 is a graph showing the relation between the thickness of the first magnetic metal layer, inclusive of an underlying layer, and the specific magnetoresistance.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Referring to the drawings, preferred embodiments of a magnetic tunnelling element and a manufacturing method therefor according to the present invention will be explained in detail.

[0017] A magnetic tunnelling element, embodying the present invention, is made up of a first magnetic metal layer 3, having a NiFe layer 1 and a Co layer 2, a tunnel barrier layer 4 formed for overlying the first magnetic metal layer 3, and a second magnetic metal layer 8, having a Co layer 5, NiFe layer 6 and a FeMn layer 7.

[0018] The magnetic tunnelling element is formed on a P-type Si substrate 9, on the surface of which has been formed an oxide layer approximately 300 nm in thickness by thermal oxidation. The present magnetic tunnelling element also has a Ta layer 9 on the FeMn layer 7 to prohibit corrosion of the FeMn layer 7. Meanwhile, this Ta layer is formed to a thickness of approximately 20 nm.

[0019] Specifically, the respective layers of the present magnetic tunnelling element were formed under sputtering conditions shown in Table 1. It is noted however that the magnetic tunnelling element and the manufacturing method therefor according to the present invention are not limitedtothese sputtering conditions.

Table 1

target	Ni-Fe	Co	Al	Fe-Mn	Ta
discharging type	DC	DC	RF	RF	RF
Ar gas flow rate	40 sccm	40 sccm	40 sccm	40 sccm	40 sccm
vacuum degree reached (Pa)	4×10^{-5} or less	4×10^{-5} or less	4×10^{-5} or less	4×10^{-5} or less	4×10^{-5} or less
sputtering gas pressure (Pa)	0.36	0.36	0.36	0.36	0.36
Discharging current (A) or Making power (W)	0.8A	0.8A	100W	200W	200W
film-forming speed(Å)	2.4	2	0.55	12.1	1.28

[0020] In the present magnetic tunnelling element, the tunnel barrier layer was formed by forming an Al layer and substantially oxidizing this Al film. The odidizing conditions are shown in the following Table 2.

Table 2

Ar gas flow rate	30 sccm
oxygen gas flow rate (sccm)	15 sccm
sputtering gas pressure	0.3 Pa
discharging type	RF back sputtering
making power (W)	20W
oxidation time (sec)	2000 sec

[0021] In the present magnetic tunnelling element, the first magnetic metal layer 3 and the second magnetic metal layer 8, each in a strip shape, are formed for crossing each other, as shown in Fig.2. In this magnetic tunnelling element, the tunnel barrier layer 4 are formed for covering at least the crossing region of the first magnetic metal layer 3 and the second magnetic metal layer 8. In the present magnetic tunnelling element, the vicinity of the end of the first magnetic metal layer 3 and the vicinity of the end of the second magnetic metal layer 8 are formed on the P-type Si substrate 9. However, since an oxide layer is formed on the surface of the P-type Si substrate 9, there is no risk of shorting of the first magnetic metal layer 3 and the second magnetic metal layer 8.

[0022] Also, in the present magnetic tunnelling element, the NiFe layer 1 of the first magnetic metal layer 3 has been subjected to uniaxial orientation processing in a predetermined direction so that it proves a free magnetization film the direction of magnetization of which is changed by the external magnetic field. On the other hand, the NiFe layer 6 othe second magnetic metal layer 8 is exchange-coupled to the FeMn layer 7 so that it proves a fixed magnetization film having a fixed magnetization in a predetermined direction. Thus, if a predetermined external magnetic field is applied to the present magnetic tunnelling element, the magnetization of the NiFe layer 1 is changed responsive to the external magnetic field. Thus, as a result of application of the external magnetic field, the magnetization of the NiFe layer 1 hasa predetermined angle with respect to that of the NiFe layer 7 of the second magnetic metal layer 8.

[0023] With the present magnetic tunnelling element, a constant current source 20 is connected to an end of the first magnetic metal layer 3 and to an end of the magnetic metal layer 8, whist a voltmeter 21 is mounted on the other end of the first magnetic metal layer 3 and on the other end of the magnetic metal layer 8, as shown in Fig.2.

[0024] In the above-described magnetic tunnelling element, the tunnel current which traverses the tunnel barrier layer flows between the first magnetic metal layer 3 and the magnetic metal layer 8, by a constant

current furnished from the constant current source 20. If, in this magnetic tunnelling element, a predetermined external magnetic field is applied, the direction of magnetization of the NiFe layer 1 is at apredetermined angle with respect to that of the NiFe layer 7.

[0025] With the present magnetic tunnelling element, the resistance value to the tunnel current is changed depending on the relative angle between the direction of magnetization of the NiFe layer 1 and that of the NiFe layer 7. Thus, if the constant current is supplied from the constant current source 20, the change in the resistance value to the tunnel current is represented as changes in voltage, so that, in the present magnetic tunnelling element, the external magnetic field can be detected by detecting voltage changes of the constant furnished current.

[0026] The magnetic tunnelling element can be used for a variety of magnetic devices, such as, for example, a magnetic head, a magnetic sensor or a magnetic memory.

[0027] Also, in the present magnetic tunnelling element, the Co layer 2 of the first magnetic metal layer 3 and the Co layer 5 of the second magnetic metal layer 8 are higher in the ratio of spin polarization than the NiFe layer 1 or the NiFe layer 6 and hence serve for achieving a higher specific magnetoresistance. That is, by arranging the Co layer 2 and the Co layer 5 on an interface between the NiFe layer 1 and the tunnel barrier layer 4 and on an interface between the NiFe layer 6 and the tunnel barrier layer 4, it is possible to increase the specific magnetoresistance of the magnetic tunnelling element.

[0028] In particular, in the present magnetic tunnelling element, the average roughness (Ra) of the major surface 3a of the first magnetic metal layer 3, stated differently, the surface of the Co layer 2, is set to 0.3 nm or less. Thus, with the present magnetic tunnelling element, the tunnel barrier layer 4 is formed on the Co layer 2 having the average roughness (Ra) not higher than 0.3 nm. Therefore, the tunnel barrier layer 4 has a substantially planar interface to the Co layer 2, while having a planar major surface.

[0029] Also, in the present magnetic tunnelling element, the second magnetic metal layer 8 is formed on the tunnel barrier layer 4, having a planar major surface, the interface between the tunnel barrier layer 4 and the second magnetic metal layer 8 is also planar.

[0030] Therefore, if, with the present magnetic tunnelling element, an external magnetic field is applied, as described above, the direction of magnetization can be positively changed, in dependence upon this external magnetic field, in the vicinity of the interface to the tunnel barrier layer 4 of the NiFe layer 1. Thus, with the present magnetic tunnelling element, the direction of magnetization of the NiFe layer 1 makes a predetermined angle with that of the NiFe layer 7, depending on the external magnetic field, in the vicintiy of the interface to the tunnel barrier layer 4. The result is that, with the present magnetic tunnelling element, the magnetic tunnelling effect is positively displayed in dependence upon the external magnetic field, as shown in Fig.3. It is noted that, in Fig.3, measurement was made in the external magnetic field of approximately ±24 kA/m (300 Oe). Also, as may be seen from Fig.3, the magnetic field of exchange coupling is 3.3 kA/m (approximately 41.25 Oe), with the resistance value and the specific magnetoresistance of the element being 25Ω and approximately 15%, respectively.

[0031] An experiment for investigating into the relation between the average roughness (Ra) and the specific magnetoresistance is now explained. In the following explanation, the average roughness (Ra) of the surface of the first magnetic metal layer 3 has been measured using an atomic force microscope.

[0032] In the present experiment, such a magnetic tunnelling element was used in which an Al layer and a Ta layer have been formed as underlying layers of the first magnetic metal layer and in which the NiFe layer was formed using high frequency induction coupling RF supporting magnetron sputtering, stated in Fig.4 as ICP sputtering. The results are shown in Fig.4.

[0033] It may be seen from Fig.4 that the smaller the average roughness of the interface to the tunnel barrier layer, that is the average roughness (Ra) of the Co layer, the larger becomes the specific magnetoresistance, and that, in order for the specific magnetoresistance to be not less than 5%, the the average roughness (Ra) of the Co layer needs to be 0.03 nm or less.

[0034] In a magnetic tunnelling element, the NiFe layer of which has been formed by the high frequency induction coupling RF supporting magnetron sputtering, the average roughness (Ra) of the Co layer could be set to 0.15 nm, thus achieving a specific magnetoresistance as high as 18%.

[0035] Meanwhile, measurment was made of the relation between the thickness of the first magnetic metal layer 3 and/or the underlying layer and the average roughness (Ra) of the Co layer in case an underlying layer is not provided for the first magnetic metal layer 3, an Al underlying layer is preovided for the first magnetic metal layer 3 and in case a Ta underlying layer is provided for the first magnetic metal layer 3. It is notedthat, if no underlying layer is provided for the first magnetic metal layer 3, the entire film thickness was changed by changing the thickness of the Co layer 2 with the thickness of the NiFe layer 1 remaining unchanged (18.8 nm). If there is provided the Al underlying layer or the Ta underlying layer, the entire thickness was changed by changing the thickness of the Al underlying layer or the Ta underlying layer, with the thickness of the NiFe layer 1 remaining unchanged (18.8nm).

[0036] The measured results are shown in Fig.5, from which it isseen that, if the Al underlying layer is provided for the first magnetic metal layer 3, the average roughness is increased with increase in the thickness of

the Al underlying layer. Conversely, if there is no underlying layer or if there is the Ta underlying layer, the average roughness is scarcely changed with changes in thickness.

[0037] It is seen from this that, if Al is used as the underlying layer for the first magnetic metal layer 3, the average roughness of the first magnetic metal layer 3 can be decreased by reducing the thickness of the Al layer. By decresingthe thickness of the Al underlying layer to decrease the average roughness of the first magnetic metal layer 3, it is possible to increase the specific magnetoresistance of the magnetic tunnelling element.

[0038] For verification, measurement was made of the relation between the overall thickness and the specific magnetoresistance in case the thickness of the Co layer 2 is changed in the absence of the underlying layer, and in case the thickness of the Al underlying layer or the Ta underlying layer is changed. The measured results are shown in Fig.6.

[0039] As may be seen from Fig.6, in the presence of the Al underlying layer, the specific magnetoresistance tends to disappear with increased thickness of the Al underlying layer. If there is no underlying layer or if there is the Ta underlying layer, a predetermined specific magnetoresistance is displayed regardless of the overall thickness. It is seen from this that, in the presence of the Al underlying layer, the magnetic tunnelling element shows predetermined changes in the magnetoresistance by reducing the thickness of the Al layer.

Claims

1. A magnetic tunnelling element comprising:

   a first magnetic layer;

   a tunnel barrier layer formed on said first magnetic layer; and

   a second magnetic layer formed on said tunnel barrier layer formed on said tunnel barrier layer, the tunnel current flowing between said first magnetic layer and the second magnetic layer via said tunnel barrier layer,
   wherein

   the surface of said first magnetic layer carrying said tunnel barrier layer has a surface roughness (Ra) of 0.3 nm or less.

2. The magnetic tunnelling element according to claim 1 wherein said first magnetic layer is formed on a metal film serving as an electrode for the tunnel current.

3. The magnetic tunnelling element according to claim 1 wherein said first magnetic metal layer has transcribed thereon the surface shape of said metal film.

4. A method for manufacturing a magnetic tunnelling element at least including a first magnetic metal layer, a tunnel barrier layer and a second magnetic metal layer, laminated together, comprising the steps of:

   forming said first magnetic layer so that its major surface will have an average roughness (Ra) of 0.3 nm or less;

   forming said tunnel barrier layer on the major surface of said first magnetic metal layer; and

   forming said second magnetic metal layer on said tunnel barrier layer.

5. The method for manufacturing a magnetic tunnelling element according to claim 4 wherein

   said first magnetic metal layer is formed by a high frequency inductive coupling RF plasma supporting magnetron sputtering method.

6. A magnetic head having a magnetic tunnelling element at least including a first magnetic layer, a tunnel barrier layer formed on said first magnetic layer and a second magnetic layer formed on said tunnel barrier layer, the tunnel current flowing via said tunnel barrier layer between said first magnetic metal layer and the second magnetic metal layer,
   wherein

   the surface of said first magnetic layer carrying said tunnel barrier layer has a surface roughness (Ra) of 0.3 nm or less.

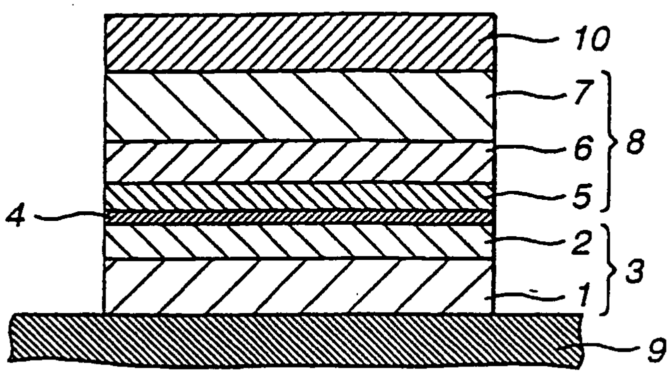


FIG.1

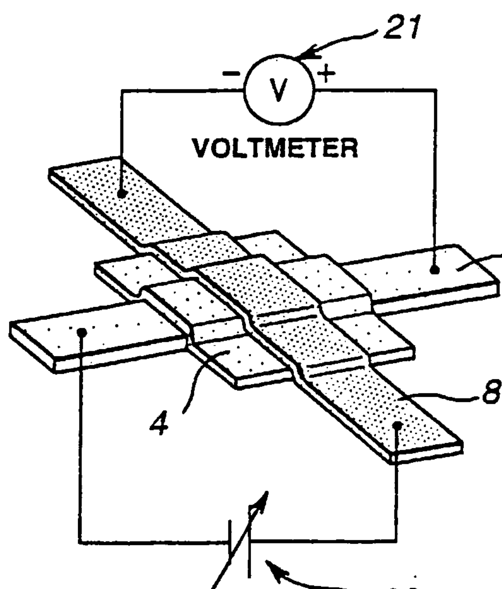
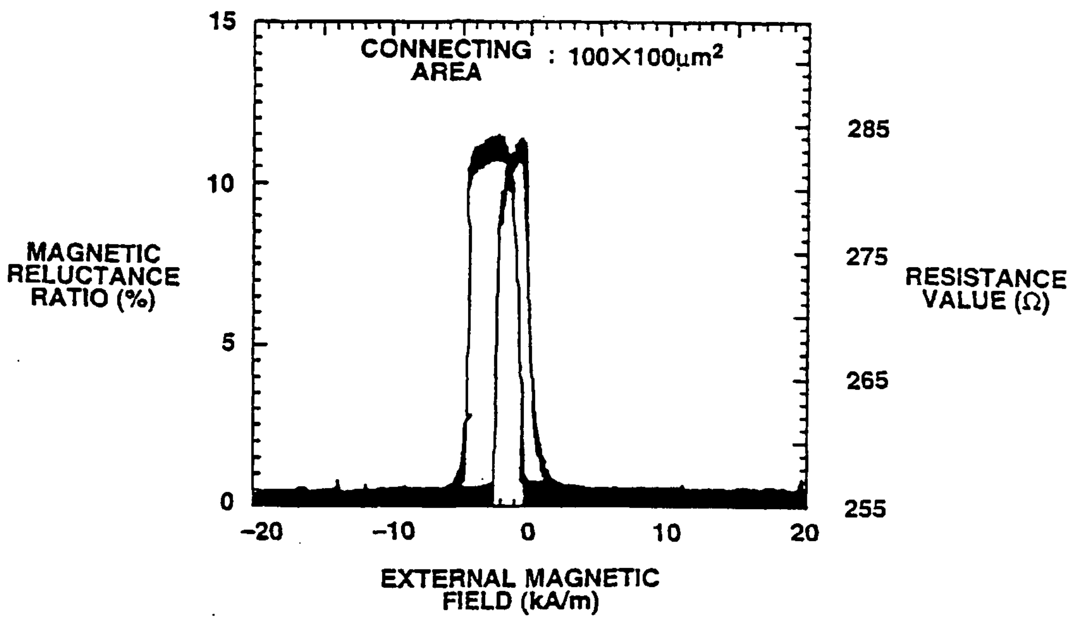


FIG.2



15
10
5
0
CONNECTING AREA : 100×100μm²
MAGNETIC RELUCTANCE RATIO (%)
285
275
265
255
RESISTANCE VALUE (Ω)
-20
-10
0
10
20
EXTERNAL MAGNETIC FIELD (kA/m)

FIG.3

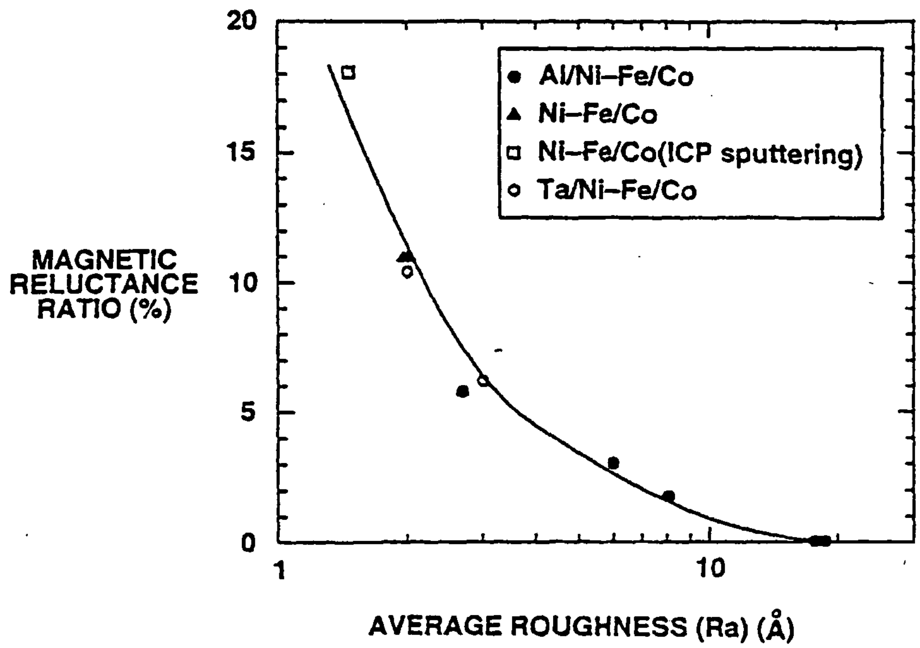
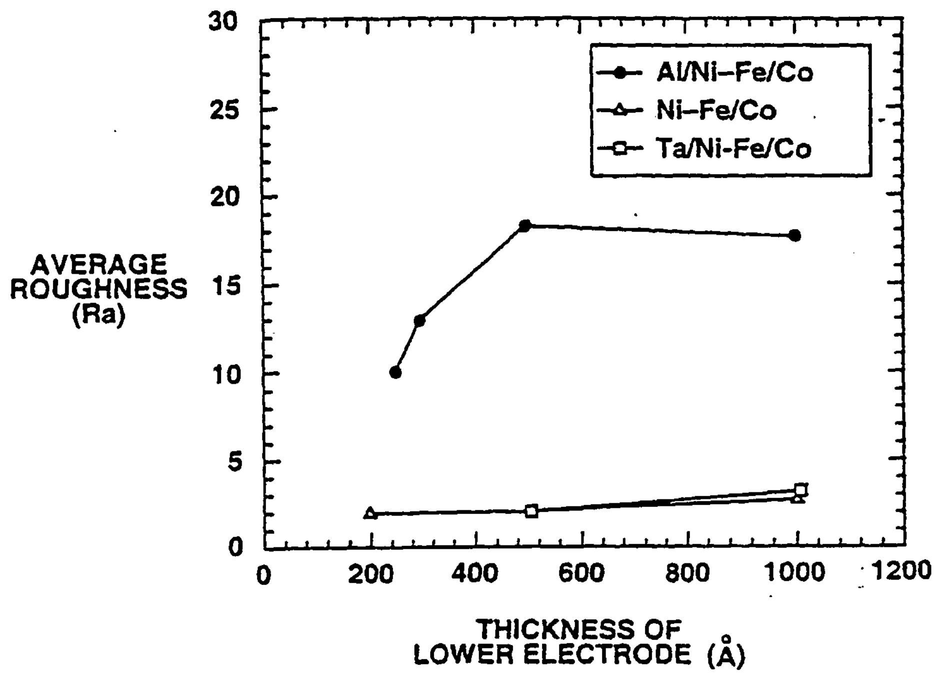
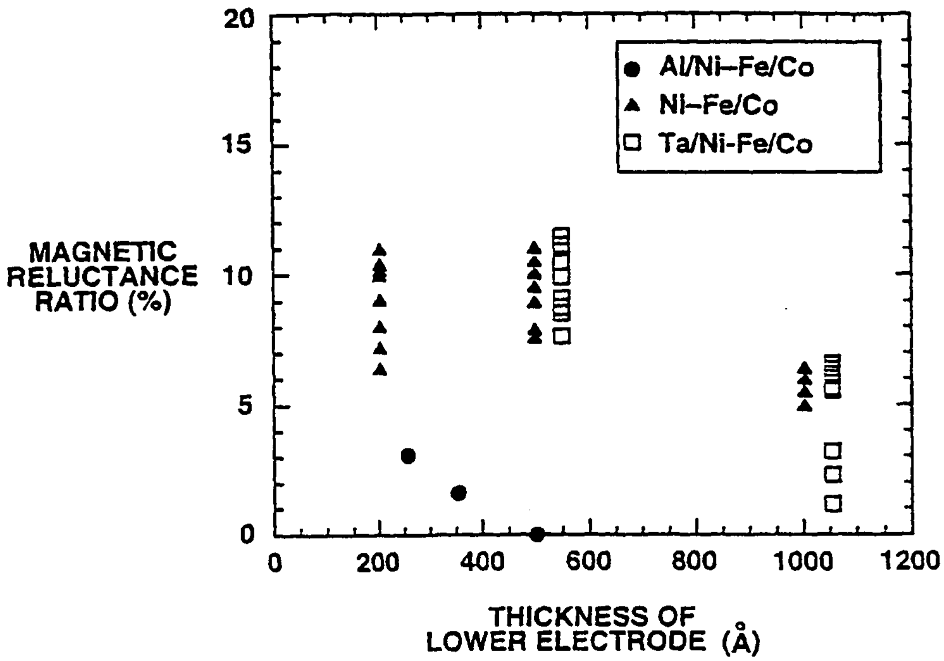

20
15
10
5
0
MAGNETIC RELUCTANCE RATIO (%)
1
10
AVERAGE ROUGHNESS (Ra) (Å)
Al/Ni–Fe/Co
Ni–Fe/Co
Ni–Fe/Co(ICP sputtering)
Ta/Ni–Fe/Co

FIG.4



Al/Ni–Fe/Co
Ni–Fe/Co
Ta/Ni-Fe/Co
AVERAGE ROUGHNESS (Ra)
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
THICKNESS OF LOWER ELECTRODE (Å)

FIG.5



20
15
10
5
0
MAGNETIC RELUCTANCE RATIO (%)
● Al/Ni–Fe/Co
▲ Ni–Fe/Co
□ Ta/Ni-Fe/Co
0
200
400
600
800
1000
1200
THICKNESS OF LOWER ELECTRODE (Å)

FIG.6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 8413

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 5 764 567 A (STUART STEPHEN PAPWORTH PARKIN) 9 June 1998 (1998-06-09) * column 1, line 64 - line 65 * ---	1,4,6	G11B5/39 G01R33/09 H01F10/08
A	MOODERA J S ET AL: "FERROMAGNETIC-INSULATOR-FERROMAGNETIC TUNNELING: SPIN-DEPENDENT TUNNELING AND LARGE MAGNETORESISTANCE IN TRILAYER JUNCTIONS (INVITED)" JOURNAL OF APPLIED PHYSICS,US,AMERICAN INSTITUTE OF PHYSICS. NEW YORK, vol. 79, no. 8, PART 02A, 15 April 1996 (1996-04-15), page 4724-4729 XP000695592 ISSN: 0021-8979 * page 4724, right-hand column, line 27 - page 4725, left-hand column, line 27 * ---	1,4,6	
A,P	B.G. PARK AND T.D.LEE: "Dependence of tunneling magnetoresistance on CoFe interfacial layer thickness in NiFe/Al2O3/NiFe tunnel junctions" IEEE TRANSACTIONS ON MAGNETICS, vol. 35, no. 5, September 1999 (1999-09), pages 2919-2921, XP002128404 usa * page 2920, left-hand column, line 30 - right-hand column, line 4 * --- -/--	1,4,6	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01F G01R G11B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	9 February 2000	Gerard, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 8413

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A,P	INDO Y ET AL: "Influence of interlayer roughness on magnetoresistive effect of ferromagnetic tunneling junctions" JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS, vol. 198, June 1999 (1999-06), pages 155-157, XP000874195 Netherlands * page 156, right-hand column, line 1 - page 157, left-hand column, line 8 * ---	1,4,6	
A,P	EP 0 898 315 A (HITACHI, LTD.) 24 February 1999 (1999-02-24) * paragraph [0032] * -----	1,4,6	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	9 February 2000	Gerard, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 11 8413

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-02-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5764567 A	09-06-1998	JP 10190090 A	21-07-1998
EP 898315 A	24-02-1999	JP 11068192 A	09-03-1999

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82